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A Discussion of the Use of Virtual Reality in Dementia

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1. Introduction

Dementia is a multifaceted disorder that impairs cognitive functions such as memory, language, and executive functions necessary to plan, organize, and prioritize tasks required for goal-directed behaviours. Ninety percent of persons with dementia present with dementia of the Alzheimer's type, vascular dementia, diffuse Lewy body dementia, or frontotemporal dementia [1]. All of these conditions affect the neurological functioning of the brain with different pathologies resulting in different clinical presentations [1]. In most, if not all cases, individuals with dementia experience difficulties interacting with their physical and social environments. The current chapter supports the use of virtual reality to explore the nature of these interactions.

2. Dementia and its impact on well-being

The most common cause of dementia is Alzheimer's disease, which leads to a physiological impairment in the functioning of neurons in the cerebral cortex [2], primarily in the hippocampus. The first stage of this type of dementia is marked by the individuals' inability to retain new information reliably and their difficulty in using cueing to enhance the retention of information. Typically, in the second stage, communication, behavioural and personality changes become more pronounced affecting daily life. In the last stage of Alzheimer's disease, most affected individuals lose their functional abilities to perform goal-oriented tasks which may include eating, grooming, and other self-care activities [3].

Vascular dementia is usually caused by a series of small strokes, resulting in an inadequate blood supply to the brain governing memory and thinking [2]. In addition to memory problems, individuals with vascular dementia may experience early gait disturbance, frequent falls, personality changes, depression, and issues related to emotional control [1].

Both diffuse Lewy body dementia and frontotemporal dementia present similar signs and symptoms manifested in both Alzheimer's disease and vascular dementia. The areas of the brain that are most affected in diffuse Lewy body dementia are very similar to those affected by Alzheimer's disease [4] but in frontotemporal dementia, the neuronal degeneration affects primarily the frontal and temporal lobes [5]. Diffuse Lewy body dementia has several hallmark features not common with Alzheimer's disease such as visual and/or auditory hallucinations, delusions, and fluctuation of cognition impairments, whereas frontotemporal dementia is marked by early behavioural changes such as aggressiveness [1] and more language-based deficits such as primary progressive aphasia [5].

Regardless of the form of dementia, many persons with dementia spend less time than their age-matched peers engaging in daily social activities. They are more likely to experience confusion and difficulties recognizing familiar environments or people at some point in the progression of the disease [2]. Even in the early stages, a simple fear of forgetting someone's name or getting lost in a new environment may impede persons with dementia from participating in social activities, as does their difficulty in communicating [1, 6]. Communication is critical to daily-life functioning as it provides a means to express one's needs or wishes [7]. Coupled with impaired memory, communication problems lead persons with dementia to have difficulties staying on topic [6, 8]. Conversational partners thus abandon their efforts for communication out of frustration, further isolating the persons with dementia.

In addition to memory and communication problems, persons with dementia have difficulty maintaining attention. When attending to a task, they may struggle to deactivate irrelevant stimuli in order to successfully perform cognitive tasks [9]. The result is that various important daily activities which require multi-tasking or undivided attention become challenging or impossible [9]. For instance, dementia might make it hard to socialize with several people at any given time [6].

All of these symptoms predispose individuals with dementia to social isolation and a progressive loss of autonomy. As such, they need to rely on individuals in their immediate environment to make sense of the world. The heavy reliance on others can ultimately be detrimental to their sense of self and well-being as they may be no longer able to exercise their own life choices.

3. The importance of environment

According to the Disability Creation Process model of functioning, a problem in life participation can be created when functional limitations (e.g. communication problems) interact with environmental factors (e.g. negative attitudes) that are non-facilitating [10]. Three interacting domains are used to describe the lived experience of individuals with functional limitations in creating successful engagement in life activities. The first domain, personal factors, includes organic systems and capabilities, which, together, entail all components of the human body that interrelate with the individuals' potential to perform

mental or physical tasks; it also includes other variables such as age, sex and socio-cultural identity [10]. In the case of dementia, this domain would include the pathophysiological changes to the brain as well as their consequences on processes such as perception, memory and language. The second domain, environmental factors, encompasses the resources – which could be either facilitators or obstacles – within the individuals' living dimensions [10]. In dementia, for instance, this might include the physical design of long term care facilities, the attitude of the general public, or the access to health coverage. These factors influence the lived experiences as they can make life easier or harder as one transitions through the journey of dementia. Finally, the last domain, social (life) participation, refers to the result of the interaction of the first two domains as they impact the lived experiences valued by the individuals and their respective socio-cultural context [10]. This domain encompasses important life areas such as work, interpersonal relationships, community involvement and so on. Overall, this model of functioning gives a framework from which to identify the role of environmental factors in creating positive or negative lived experiences. For example, a simple goal-oriented task such as get-a-book-sit-and-read may be challenging for persons with dementia due to impaired executive functions. That is, they may simply not think of initiating the task of reading the book or may have difficulty planning the steps for executing the activity. An environmental cue such as a chair located near a bookcase might help persons with dementia improve their planning, organizing, and prioritization (i.e. executive functions) – to get a book, sit, and read. The impairment (i.e. dementia) in this example does not change, but the environment facilitates the realization of the activity. Fundamentally, the Disability Creation Process model offers a framework from which to understand the relationships amongst all the domains and help identify areas which might improve the lived experience through the modification of either or all of the domains.

If we are to improve the lived experiences of persons with dementia, attention must be allocated to altering the environment while other investigations continue to strive for a cure. Unfortunately, current pharmacotherapies for dementia act on the symptoms or succeed in slowing its progression but fall short of addressing the underlying pathology of dementia [11-13]. While environmental interventions have been the key to improved quality of life in dementia until a cure is found, it is important to not create overly facilitating environments. Environments that under-challenge persons with dementia may further deteriorate persons with dementia's quality of life by under-using their existing abilities. Lawton and Nehemow [14] describe this as 'environmental press'. In order to ensure an ideal zone of maximum comfort, the demands of the environment (weak to strong) should be balanced with the individual's level of competence (low to high). Situations where there is a strong environmental press on an individual with lower levels of competence will result in negative affect and maladaptive behaviour. Likewise, environments that are weak and demand little of the individual who has higher levels of competence will also result in negative and maladaptive behaviours. In the case of the get-a-book-sit-and-read task, placing a chair right beside the bookcase in addition to hiring an attendant who will get the book may prevent persons with dementia from using any residual planning processes, thereby fostering a sense of helplessness and loss of personhood.

The balance between the demands of the environment and the capabilities of the individual is difficult to maintain and study in a systematic fashion. One of the biggest limitations is the trade-off between experimental control and realism [15]. In other words, the more experimental control researchers have over an experience, the less ecologically valid it will be. The use of immersive virtual environment technology or virtual reality may be the answer to this shortcoming.

Immersive virtual environments allow researchers to create very realistic environments while maintaining a high level of experimental control [16]. Immersive virtual environments technology has been used in therapy for phobias [17, 18], stress [19-21], anxiety [22, 23], exercising [24], and memory problems [25, 26], yet it has hardly been used in the area of dementia. Several reasons might explain the dearth of publications on this topic. On the one hand, scientists might assume that persons with dementia cannot use the necessary paraphernalia to engage with virtual environments. On the other hand, there may be a concern that the cognitive difficulties associated with dementia prevent participants from attaining the level of presence necessary to engage with these environments.

4. Other media used in the area of dementia

As the numbers of individuals with dementia rise, there is an ever increasing interest in the use of technology to improve safety and quality of life. Smart Home Technology and environmental control systems are prime examples of emerging new technologies that have shown some success in facilitating the environment for individuals with disabilities, as well as improving their safety. Smart Home Technology is found in homes that are programmed to facilitate independent living. These homes include, for example, lights that turn on when the inhabitant gets out of bed and systems that remind individuals with cognitive problems to turn off the stove. These are only a few examples of the large amount of technologies integrated within these homes to assist with everyday living [27]. While these types of technologies are seen as promising in assessing function, Brandt and colleagues, using a systematic review of the literature, found no solid evidence of their use in the area of dementia [27]. Only one group of authors in their selected studies included participants with cognitive difficulties (i.e. participants with traumatic brain injury) while most examined the performance of these technologies with participants with primarily physical limitations. Even in these populations with physical limitations, the evidence was inconclusive.

Bharucha and colleagues [28] searched the literature for strong evidence supporting the use of environmental assistive technologies for individuals with dementia. These systems use a large range of different sensors and artificial intelligence to assist the person with dementia as well as help ensure their safety. CareWatch consists of door opening and bed occupancy sensors that will alert the caregiver if the person with dementia exits the home at night. COACH is a system that can be used to guide people with dementia in hand washing. It provides verbal prompts and monitors to remind the person to wash their hands and assist them through the process [28]. These technologies allow for greater independence, security

and overall quality of life for both the person with dementia and the caregiver, but strong evidence is still lacking. Bharucha and colleagues [28] found a dearth of studies focussed on dementia as a target population. When it came to individuals with cognitive problems, the search yielded studies whose participants were primarily young with nondegenerative conditions such as traumatic brain injuries. Again, the results were inconclusive as to the impact of these technologies. The authors call for more high quality investigations on the use of these technologies with dementia and for a need for more cost effectiveness data on these systems. In light of the cost of some of these systems, perhaps it would be worthwhile investing in experimental trial protocols that use technologies such as virtual reality. Rather than build these environments, virtual reality might help test their applicability in a virtual world prior to going to market.

On a more therapeutic note, technologies such as robot therapy and 'video respite' have shown some preliminary promise. One such example is the use of a seal robot named Paro which was designed for use with the elderly [29]. As an accompaniment and social stimulator to individuals with dementia living in long-term care facilities, its integrated sensors allow it to interact in various ways when it is touched. While the authors claim its widespread use, along with other robotic animals, the evidence for reducing levels of depression and improving quality of life in people with dementia needs more support. While the participants seemed to interact well with the 'virtual' animal, the evidence for diminishing stress and improving interactions is scarce for the population of individuals with dementia.

Similarly, 'Video Respite' has shown only preliminary success in regards to people with dementia [30]. Video respite is a videotape application that simulates the visit between an actor in the video and the person with dementia. For instance, people with dementia are seated in front of a television screen while an actor 'reminisces' with them about life in an earlier time. It is used mainly to provide respite for the caregiver as the person with dementia is occupied by the video. People with dementia watching the videos were subjectively found to be calmer and their disruptive behaviours were reduced.

The introduction of various types of technological media for use with people with dementia appears to be increasing. However, the evidence to support their use in helping people with dementia and their caregivers is scarce. Several interesting hypotheses can be generated however from these data. First of all, could media such as virtual reality be helpful in testing the preliminary effectiveness of these technologies prior to their development? With the advent of augmented reality, a person with dementia could potentially be immersed in a virtual apartment with simulated technological 'aids' to functioning. The impact of each environmental aid could be evaluated individually as well as in combination with other aids. Second, the preliminary evidence with robot therapy suggests that individuals with dementia may be able to obtain some level of presence with a 'non-real' animal. Is this indicative that they are able to obtain presence in other forms of media such as immersive virtual reality?

5. Immersive virtual environment technology and individuals with dementia

There is still insufficient evidence for concluding that immersive virtual environment technology can or cannot be used with persons with dementia. Flynn et al. [31] incorporated a user-centred-approach and found that it is feasible to immerse persons with dementia in a virtual environment via immersive virtual environment technology. The authors reported that persons with dementia felt a sense of control and enjoyed the interaction in virtual environments, as well as demonstrated little difficulty in manoeuvring a joystick [31]. There was also no significant deterioration in terms of simulator sickness and well-being [31].

Cushman, Stein, and Duffy (32) examined the feasibility of using immersive virtual environment technology to detect navigational deficits in people with Alzheimer's disease. Users had to navigate their ways through both a real hospital lobby and a virtual hospital lobby. By using eight navigation subtests, the authors found that the use of virtual environments was an effective method to assess navigational skills, and that quantifying a virtual-world navigational performance is easier and less time-consuming than quantifying a real-world navigational performance. In another study [33], Shaick, Martyr, Blackman, and Robinson used virtual reality to observe how a physical outdoor environment could affect way finding. Persons with dementia were immersed within an outdoor virtual environment and were asked to go for a walk. Many facilitators and barriers which might affect orientation were incorporated such as larger street signs, street signs with pictures of uncommon objects, street signs with names only or unattractive street layouts. The authors found that if the street felt unappealing for the persons with dementia, it became a barrier to the overall success of the walk. In 2009, the same environments were used to examine spatial navigation in healthy older adults as opposed to older adults with dementia [34]. The users were asked to navigate a virtual neighbourhood and subsequently asked to recognize certain city buildings and objects. Young adults were quicker and more accurate than both older adults and individuals with Alzheimer's disease, while individuals with Alzheimer's disease had more difficulty with the recognition task than normally-ageing participants. In summary, these studies provide some evidence that, at least in the earlier stages, persons with dementia can use the paraphernalia and be successfully immersed in virtual environments. While these studies have shown some success with the use of virtual reality for assessing navigation, the question remains as to whether persons with dementia can obtain presence for all types of functional problems.

6. Presence and dementia

Early descriptions of presence define it as believing oneself to be in an environment while being physically located in another [35]. While presence is a necessary precursor for successful use of virtual environments, Riva, Waterworth, Waterworth and Mantovani [36] remind us that obtaining presence is not a media-dependent phenomenon. That is, the ability and belief that one can act upon one's environment and at the same time be influenced by this environment exists regardless of the medium of transmission [36]. In

addition, attaining presence requires constant processing between human sensory and cognitive skills [37]; hence the concern that it might not be feasible with persons with dementia. Since there is very little literature pertaining to the use of virtual reality with persons with dementia, a better understanding of the phenomenon of presence will help with our understanding of how people with dementia might interact with their environments.

Riva et al. [36] suggest that presence is what links our volitional motivation to act upon our environment and our cognitive adjustment to changes in our environments. These interactions however can be explained as they evolve over several layers [38]. According to these authors, the first layer, proto presence, involves an unconscious sense of the self in space which is constructed using proprioceptive information. At this level the individual obtains a sense of how his body moves in the environment, and the challenge in virtual reality is to create technology that is sensitive to this proprioceptive feedback. The small literature reported above on the assessment of navigation suggests that individuals with early dementia are able to attain this layer of presence. Until the technology is able to capture proprioceptive information more systematically, we may not be in a position to explore this level of presence in greater detail in the virtual environment [38]. Nevertheless, preliminary studies are promising that persons with dementia are indeed capable of obtaining proto presence.

In the second layer, core presence, the individual is able to determine what is real and what is not real based on the processing of perceptual information [38]. The perceptual information thus captured forms an integrated percept that is continually adjusted in real time according to current changes in the environment. The emphasis is on the here and now and the individual who obtains presence is influenced by these changes. The vast literature on environmental modifications to alter the expression of disruptive behaviours in dementia [35, 36] suggests that the actions of people with dementia can somewhat be mediated by a systematic control of the environment. For instance, persons with advanced dementia have been shown to improve real life navigation by the addition of visual environmental cues [41]. According to Riva et al. [36] the saliency of the stimuli is very important at this level since it is the perceptual information which creates this layer of presence. Once again the studies on navigation would suggest that persons with dementia are sensitive to the saliency of the stimuli as Schaik et al. [33] were able to create obstacles and facilitators by modifying the road signs. Persons with dementia were influenced by the visual nature of the information they received in the immersive virtual environment.

In the third layer of presence, extended presence, Riva et al. [38] argue that the individual uses cognitive processes to understand the meaningfulness of the environment. These processes require the individual to process the information received through levels one and two and compare it to information in memory to attach meaning and relevance. Based on what we know about the cardinal signs of dementia, persons with dementia should have considerable difficulties with this level of presence. According to Riva et al. [36], the individual in an immersive virtual environment will make hypotheses about what will

happen in the environment as he makes sense of what he sees. It is plausible to assume that individuals with dementia may not be able to make these hypotheses or may make erroneous ones. If this is true, presence could only be achieved as high as the core level where information is processed online in the here and now.

Bouchard et al. [42] observed that activation of the parahippocampal cortex is correlated with a greater sense of extended presence [38]. This area of the brain is important in giving contextual meaning to scenes and locations [42]. According to these authors, the lateral surface of the occipital lobe, fusiform gyrus, and adjacent insula cortex are involved in providing virtual reality users with awareness in detecting the discrepancy between the virtual environment and the physical world; one might refer to this as core presence [38]. Since Alzheimer's disease can impair the functioning of either or all the brain regions stated above [43-46], one might argue that persons with dementia might not have the cognitive ability to analyze information within context and understand the meaningfulness of the environment. Hence, in dementia one might hypothesize that the processed information about the environment does not generate the same intention as was meant. It might be possible that individuals with dementia may find meaning in what they see but may be attaching the perceived information to wrong meanings in memory because they cannot access their memories as efficiently and effectively as individuals without dementia. It seems that the virtual environment might be ideal to test out this theory.

Current judgement theory indicates that our decision-making is governed by a two-system view in which the intuitive mode is monitored and corrected, if necessary, by the controlled mode [47]. The operation for the intuitive mode is automatic, and it is responsible for generating impressions [47]. In contrast, the operation for the controlled mode is more effortful as it is involved in deliberate reasoning [43]. In the event whereby the controlled mode is malfunctioning, as is often the case with persons with dementia, it is likely the intuitive mode would dominate. Persons with dementia might continue to believe in the impression they generated, regardless of whether it is right or wrong, given that the intuitive mode is not overridden by the controlled mode. In addition, the lack of a controlled mode reduces the ability for persons with dementia to experience doubt, a cognitive ability that allows the subject to deal with incompatible thoughts on the same subject [47]. This suggests that persons with dementia may be able to imagine, interact, and develop an emotional link towards the subjects within the virtual environment without a dilemma arising around whether it is real or not. Overall, this reasoning might suggest that persons with dementia may experience a greater sense of Riva et al.'s [38] core presence but a lesser extent – or erroneous – sense of Riva et al.'s [38] extended presence.

7. Potential of virtual reality as an assessment tool in dementia

Immersive virtual environment technology gives researchers the opportunity to study how persons with dementia interact with their environment and which elements are most

facilitating or creating the least distress while capitalizing on residual cognitive resources. Virtual reality technologies offer the potential to capture the impact of physical environments, as well as social interactions by deconstructing these environments. Further research into this area will help develop a better understanding of how persons with dementia can act to influence their environments and how changes in the environment can affect them. The objective may not be to learn a new skill but rather to understand how to better design physical spaces or modify social environments for better quality of life.

One of the advantages of virtual reality is the potential to control and modify these environments when it cannot be easily, or completely, changed outside of the virtual world. For example, human interaction and social presence would be particularly useful to examine in persons with dementia using virtual reality. More detailed knowledge about how others influence interactions with persons with dementia would help offer advice for caregivers on how to interact with this population. For instance, one might manipulate the verbal and non-verbal aspects of communication of virtual humans as they interact with the user [16, 48]. As Garcia et al. [48] pointed out, if we want to study the impact of tone of voice on persons with dementia during social interaction, we could create experimental conditions where a virtual human modifies tone of voice while maintaining neutral facial expressions. This type of experimentation is impossible outside of the virtual environment since human conversational partners cannot voluntarily isolate these parameters. Knowing more about the impact of these changes in the environment may lead to remarkable changes in clinical approaches and improve quality of life. Immersive virtual environment technologies offers a promising avenue for testing these hypotheses as well as helping us to better understand the processes involved in presence.

8. Potential of virtual reality as a training tool in dementia

It is unlikely for persons with dementia to acquire new skills as they tend to experience rapid deteriorations in their brain mappings throughout the journey of dementia. Such progression, however, might be slowed down by medications and brain-stimulating activities based on the theory of neuroplasticity – the ability of brains and nervous systems to reconstruct new cellular synapses as a result of the interaction with enriched environments [49, 50]. Nonetheless, the perception of such environments may be different for individuals, and it would be financially impossible to construct a customized enriched environment for every individual. Virtual Reality has the potential to fulfil this requirement at a lower cost.

In addition, virtual reality would allow researchers to systematically study the various desired brain-stimulating activities as a function of the rate of neuroplasticity experienced in persons with different types of dementia. It is known that dementia of different types may experience deterioration in different regions of the brains; thus, it is very important to

explore the possibility of conducting such ‘targeted’ brain-stimulating activities in light of deteriorating regions of the damaged brain.

9. Conclusion

It is surprising to see how little immersive virtual environment technology has been used with individuals with dementia, one of the largest growing clinical populations. The Disability Creation Process model of functioning suggests that each individual may experience the impact of diseases differently. It highlights the role of environmental factors in creating situations where social participation may be limited. Immersive virtual environment technology may prove to be useful in testing the role played by physical and social environments by immersing persons with dementia in virtual environments and observing the results following the process of virtual-environment-remodelling [33]. Immersive virtual environment technology can help us understand more about how persons with dementia interact with their environments – whether physically with the objects or socially with other people in their surroundings. Should the remodelling improve the lives of persons with dementia, such modification may be implemented outside the world of virtual environments.

Until a cure is found, our most promising interventions will rely on environmental modifications. Should we confirm that persons with dementia are unable to obtain extended presence, as argued in this paper, but can function at the level of core presence, this may prove to be a satisfactory level for improving quality of life. Persons with dementia typically function in the here and now and immersive virtual environment technologies might prove to be useful in creating pleasant virtual worlds where they may find it easier to interact while maximizing residual cognitive processes. These worlds may offer much needed respite to both formal and informal caregivers while allowing pleasant, meaningful activities in the here and now for persons with dementia. The literature is clear that success in lived experiences is dependent on both the personal and environmental factors. Immersive virtual environment technology can shed an important light on one of these domains.

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